focus on
Microscopy & Microtechniques

Studying Materials at the Nanoscale: University of Huddersfield Offers Unique Facilities

The use of increasingly powerful microscopes to observe the spatial arrangements of atoms has been vital in pursuing understanding of the behaviour of solids (metals, semiconductors and insulators), particularly when the properties of these materials can be influenced by various types of defect.

In 2011 Professor Steve Donnelly, Dean of the School of Computing and Engineering at the University of Huddersfield, set up a research group based around the use of electron microscopy to study the interaction of energetic particles with matter. With relevance to materials for space, the semiconductor industry and particularly to the nuclear industry, this research informs decisions regarding the materials used in the next generation of fission and fusion reactors and waste encapsulation and storage.

"The Electron Microscopy and Materials Analysis (EMMA) research group, led by Professor Steve Donnelly, is primarily focused on the changes in materials caused by irradiation capable of displacing atoms from their lattice sites. Areas of interest include nuclear structural and waste storage materials, the modification of nanostructures such as nanowires or graphene and the processing of semiconductors," explained Senior Research Scientist Dr Jonathan Hinks.

"As well as the industrial and technological applications, our work is often at a fundamental level exploring the physics behind the evolution of microstructures under displacing irradiation. Because of the dynamic nature of the effects in which we are interested, we designed and constructed the Microscope and Ion Accelerator for Materials Investigations (MIAMI) facility. This instrument consists of a Transmission Electron Microscope (TEM) which allows materials to be studied on the nanoscale combined with an ion accelerator which can induce atomic displacements and also implant atoms into a sample whilst it is under observation in the TEM. By changing the ion energy, ion species and sample temperature it is possible to explore different environments and phenomena. For example, inert gas accumulation in tungsten for a nuclear fusion reactor or the structural damage caused to silicon during the manufacture of a semiconductor device," Dr Hinks said.

Investigating Materials Damage

Recently awarded £889,839 by the Engineering and Physical Sciences Research Council (EPSRC), the team are currently using MIAMI to investigate damage, such as fracturing, caused by irradiation of the materials that are used for the construction of reactors and for the long-term, safe disposal of radioactive waste.

Professor Steve Donnelly

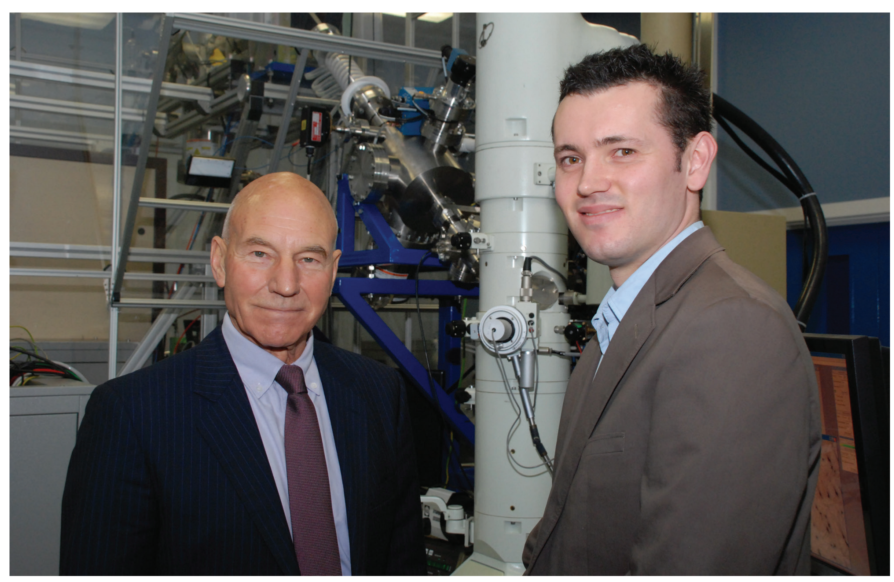
"The project is about producing a base line of experimental evidence," said Dr Hinks, who explained that the research team would use ion beams to irradiate thin samples of material.

"You have to have a very thin piece of material – typically 100 nanometres or less – otherwise the electrons won't get through and you can't see anything," said Dr Hinks. Using electrons in the same way that a conventional microscope uses light, MIAMI enables researchers to see inside the ultra-thin samples of material and witness changes caused by irradiation, including the build up of gas bubbles.

The amount of ion energy and temperatures can be varied during the experiments and the result will be a database of information about the effects of irradiation at the nanoscale that can then be scaled up by scientists and engineers selecting materials for reactors and for waste disposal.

The findings of the project will be relevant to the Generation III+ reactors soon to be constructed in the UK. The proposed fusion reactor at Hinkley Point C, for example, will be a 3.2 GW nuclear power plant consisting of two 1.6 GW European Pressurized Reactors (EPRs); harnessing reactions similar to those producing the Sun's energy, it will also have components subjected to similar extreme conditions.

The materials for these have already been selected, said Dr Hinks, but regulatory authorities need constant updates on safety issues and the MIAMI data will enable engineers to predict how reactors will perform over time. The work of EMMA on the choice and design of appropriate materials for reactor components is therefore of crucial importance.



Dr Jonathan Hinks (right) with the University's Chancellor Professor Sir Patrick Stewart.

Training New Nuclear Scientists

There are two strands to the EPSRC-backed project – structural nuclear materials, and nuclear waste storage. The MIAMI research group will be augmented by two post-doctoral researchers who will each be assigned to one of the strands. The researchers will be highly-qualified, but will also receive training in aspects of nuclear science.

An important dimension of the project is the training of new nuclear scientists, said Dr Hinks. This is to help correct a deficit in the UK. "Because there was a lack of investment in nuclear research and development in the 80s and 90s, the demographic of the people who work in the industry has shifted towards retirement age. So there is a skill gap, particularly serious when you consider the expansion of the UK's nuclear capacity that is now planned."

MIAMI is a custom-designed facility consisting of a Jeol 2000FX transmission electron microscope connected to an ion accelerator. It uses ion beams to simulate the effects of radiation damage in-situ and allows for nanoscale examination. It is the only such facility in the UK and one of only two in Europe, the other being the JANNuS laboratory at Orsay in France.

The EMMA research group also operate a Jeol-3010 TEM capable of lattice imaging, an FEI Qaunta dual beam Focused Ion Beam (3D SE/FIB) system for machining at the nanoscale and an FEI Quanta 250 Field Emission Gun Environmental Scanning Electron Microscope (250 FEG ESEM).

Leading Research in the Field of Accelerator Science

THE University of Huddersfield now houses a world leading facility in the field of accelerator science. The Medium Energy Ion Scattering Accelerator (MEIS), formerly located in the Science and Technology Council's Daresbury Laboratories, UK, has been relocated, rebuilt and rebooted at the International Institute of Accelerator Applications (IIAA) sited on the Huddersfield Campus. It received its official launch at the Fourth Annual Symposium on Accelerator Applications, a day-long sequence of scientific papers and presentations taking place at the IIAA.

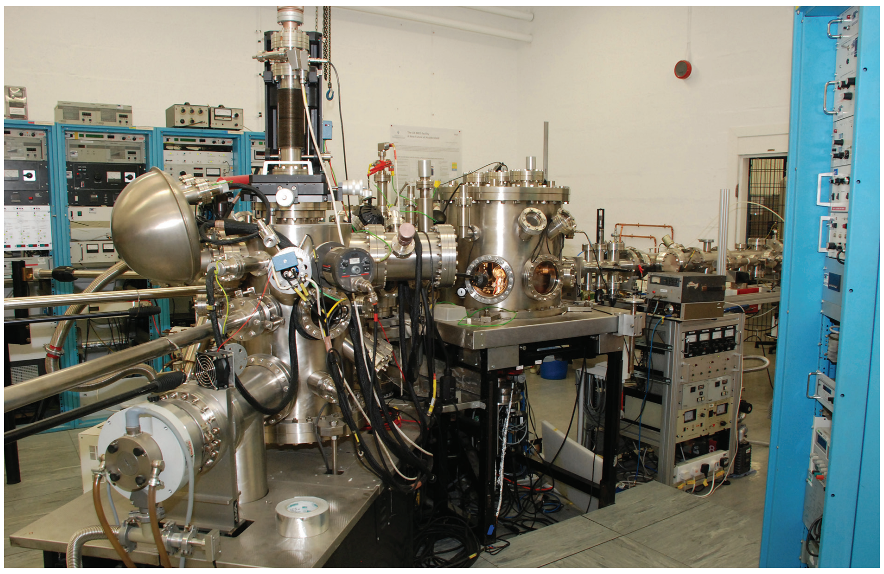
Professor Jaap van den Berg, Professor Sue Smith, Professor Bob Cryan, Professor Roger Barlow

The switch-on ceremony was introduced by IIAA Director Professor Roger Barlow and presided over by University Vice-Chancellor Professor Bob Cryan and Professor Susan Smith, Head of the Daresbury Laboratory.

Fully Operational Accelerator

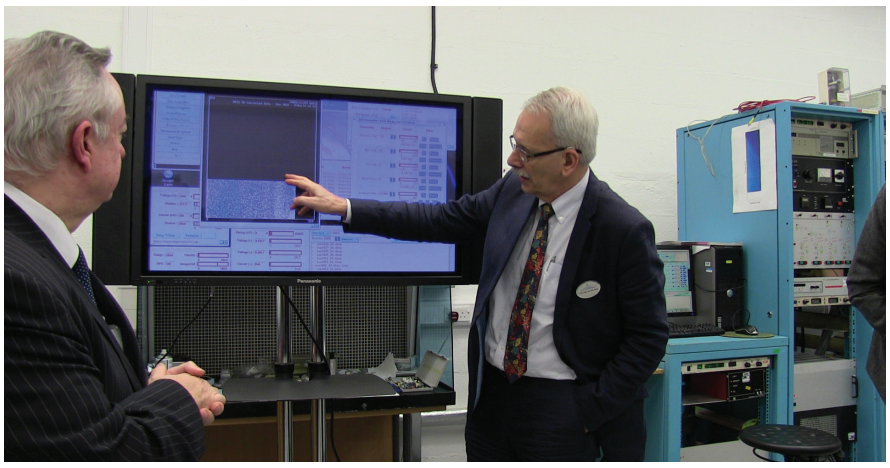
Operational at Daresbury since 1996, STFC funding for the facility expired in 2010; Professor Smith was very happy to help with the relocation and provided some of the technical expertise required to reinstall MEIS in its new home.

Professor Bob Cryan said: "We are very proud to be home to the International Institute of Accelerator Applications and we are very proud that it now has its own fully operational accelerator. Not only is it a fully-functioning medium energy ion scattering facility, equipped with a new and optimal 200 keV ion accelerator – which is rare enough – but is also fully accessible to a wide range of users. It is of great benefit to the scientific community and the private sector."



The MEIS accelerator at Huddersfield

During the Annual Symposium IIAA's Professor Jaap van den Berg, who played a central role in moving and reinstalling the accelerator, described the various phases of the project which began in 2011; some components, such as the original high voltage source platform for the accelerator was too large to bring to Huddersfield and so a new one was constructed at the IIAA's labs. In May, 2012, a total of 100 crates required eight 3.5 tonne van loads and two 18 tonne lorry loads to bring the components of MEIS from Daresbury to Huddersfield.



Professor Japp van den Berg reviews a data run

4th Annual Accelerator Symposium

Report by Roger Barlow, Research Professor, University of Huddersfield

The Huddersfield Annual Accelerator Symposium, established as a regular event at the International Institute for Accelerator Applications (IIAA), serves a dual purpose. First, it is an event that brings leading accelerator specialists from the UK and beyond to talk at our university, for the benefit of our students and staff. Secondly it acts as a shop window to outside visitors, showing them our accelerator activities, particularly focussing on recent developments, as changes here in Huddersfield are happening fast.

This year's symposium on 3rd March was special as we used it to celebrate and announce the opening of MEIS in our labs. We heard the saga of the disassembly, move, and rebuilding of the MEIS facility from its former home in Daresbury to its new one in the Ramsden workshops. The Vice Chancellor was joined by Professor Susan Smith, the Head of Daresbury Laboratories: they made short speeches and started the data-taking run - which worked, much to everyone's relief.

But that was just part of the day. Before that we had a morning of presentations with a 'medical flavour; Rob Edgecock' of Huddersfield and Oliver Heid of Siemens both discussed some of the possibilities for imaging and therapy that new isotopes could offer and the accelerators and target systems that could produce them on a small scale in every hospital. In future a doctor should be able to choose from a much wider range of treatments and have procedures done there and then, rather than waiting for a delivery from a remote centre. Then Karen Kirkby, the recently appointed Professor of Proton Therapy at Manchester, set out the plans for establishment (long overdue!) of a full proton therapy treatment system in England, with new centres in Manchester and London. This is a very exciting development that many of us have been urging for years and now things are actually beginning to happen, though it will be some years before the first patients are treated.

In the afternoon, after the opening ceremony we returned to the talks, this time, as appropriate, with an emphasis on low energy ion beams. Tim Noakes from STFC covered the applications of MEIS and showcased some previous results, Roger Webb from the University of Surrey presented other ion beam facilities and what they could do and finally Stephen Donnelly, another local, described the MIAMI facility at Huddersfield: a combination of ion beam and electron microscope. He showed some impressive videos of the behaviour of materials when being bombarded by radiation and he told us of plans for the recently approved £3.5 million successor, MIAMI 2.

50 delegates registered, from 11 different institutes, mainly from the North West of England, but the number in the audience was swollen by many Huddersfield staff who dropped in to the occasional lecture. The audience ranged from a 6th form student observer to a retired CERN expert who happened to be in the area. The 3MBIC meeting room was just the right size and made for an ambience that was not too academic: the expert speakers rose to the challenge of communicating their enthusiasm to the varied audience and the questions at the end of the talks continued lively right up to the close.

It's going to be a hard act to follow, but we certainly hope to plan an even more exciting event in 2016.

Slides from the talks are on the website https://indico.cern.ch/event/369677/

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